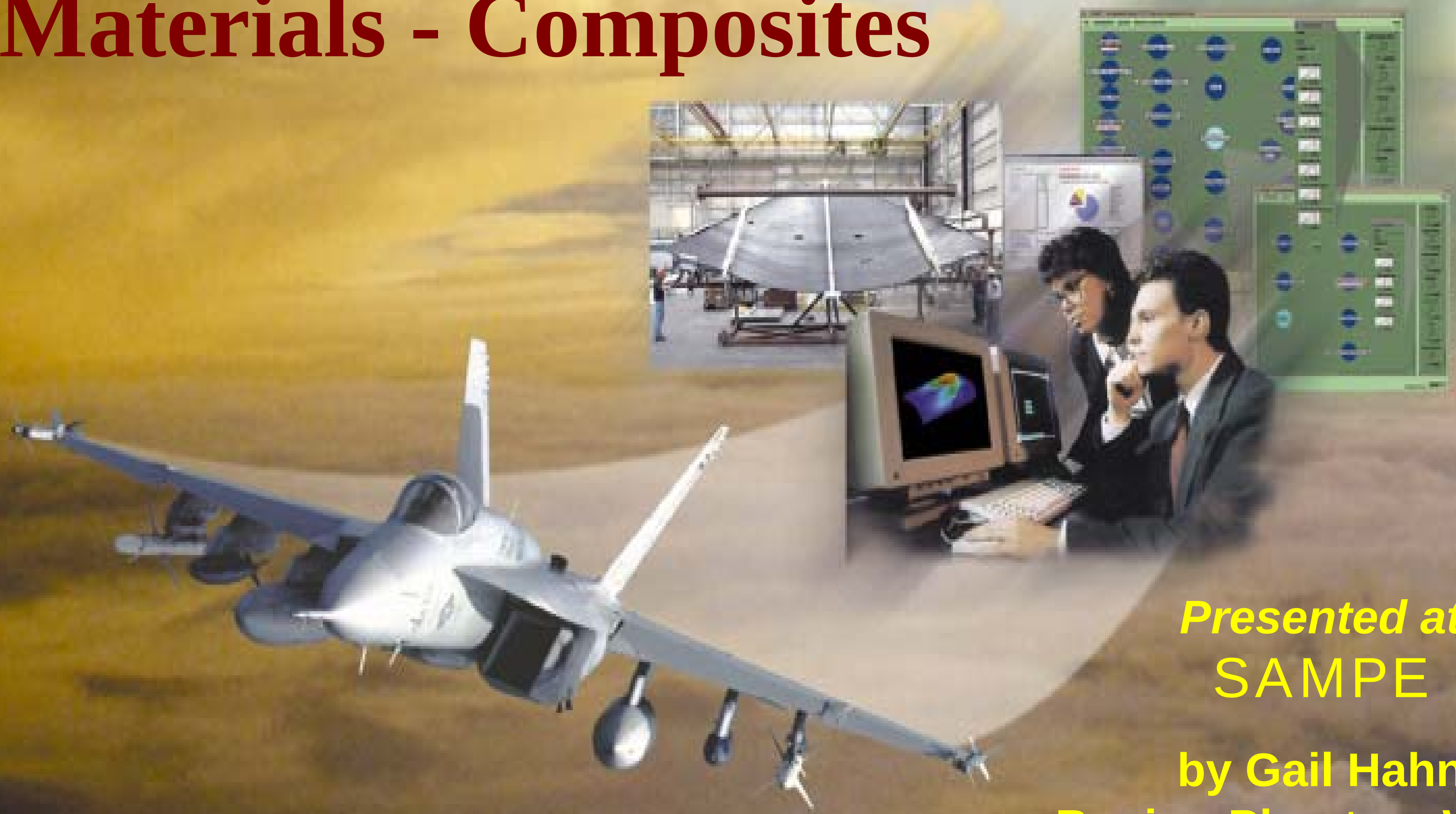
Accelerated Insertion of Materials - Composites



Presented at

SAMPE

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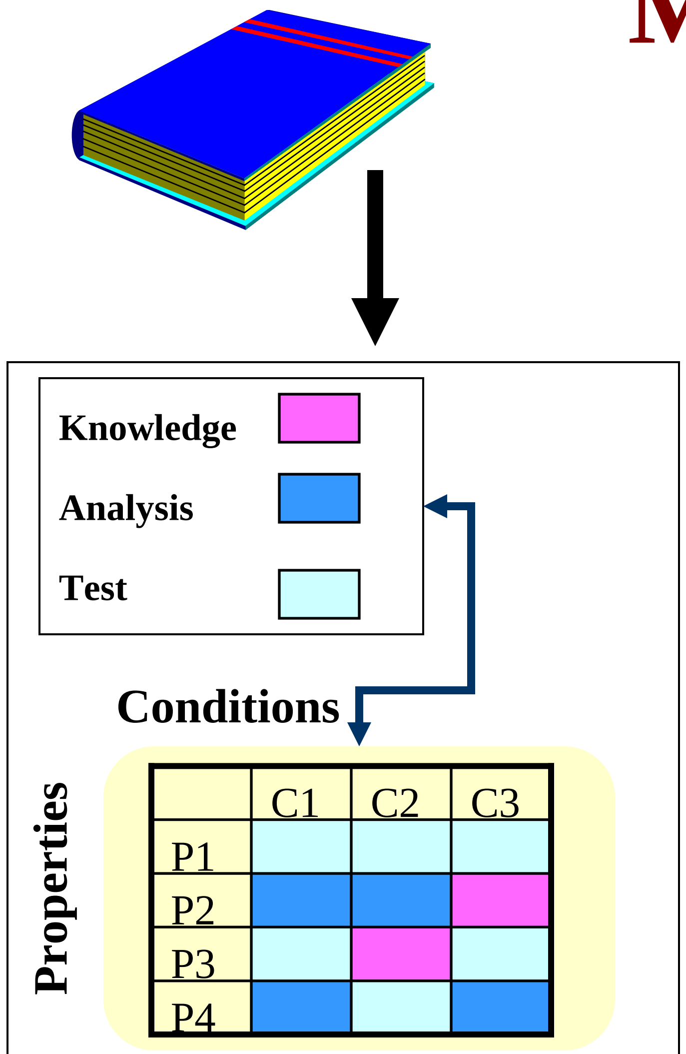
Accelerated Insertion of Materials Goals



Designer's View
Each data point has its own "resume"

Transform traditional materials database and qualification practice into an efficient and interactive process fully integrated into the available design tools and design community that retains/improves upon the robustness and reliability of traditional practice.

Use the right source (model, experiment, experience) to fill in the data

Reach for robustness not precision. Know the confidence in the data when needed.

Models can (and will) evolve – confidence in the knowledge of errors and uncertainty is what is needed

Specific Objectives for Phase I

Establish a methodology for accelerated insertion of materials into defense structures.

- Phase I
  - Establish a designer knowledge base (DKB) for a currently employed material
  - Populate with data from models and/or experiments directed by the new methodology
  - Fully integrate into design tools
  - Validate against known material database
  - Demonstrate reduction in insertion time

AIM-C is on track to meet all AIM Phase 1 Objectives

AIM-C Alignment Tool

The Objective of the AIM-C Program is to Provide Concepts, an Approach, and Tools That Can Accelerate the Insertion of Composite Materials Into DoD Products

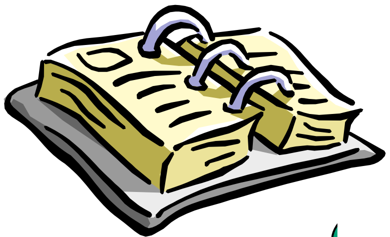
AIM-C Will Accomplish This Three Ways

Methodology - ***We will evaluate the historical roadblocks to effective implementation of composites and offer a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.***

Product Development - ***We will develop a software tool, resident and accessible through the Internet that will allow rapid evaluation of composite materials for various applications.***

Demonstration/Validation - ***We will provide a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.***

AIM-C Will Validate the Process



Methodology
That Links an Accelerated Process to the Knowledge Requirements

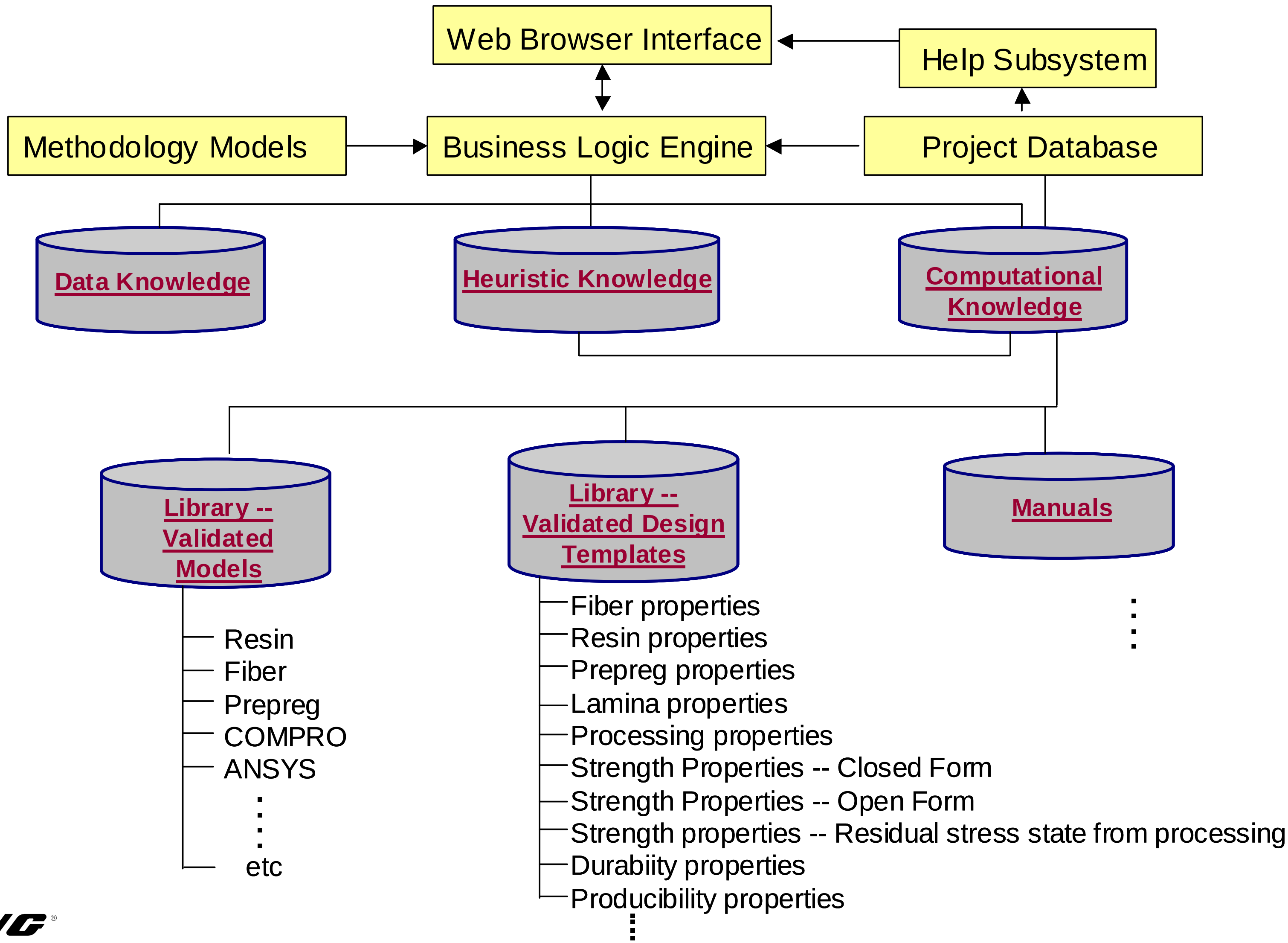
Embedded In

Software
That Links the Methodology to Knowledge, Analysis Tools, and Test Recommendations

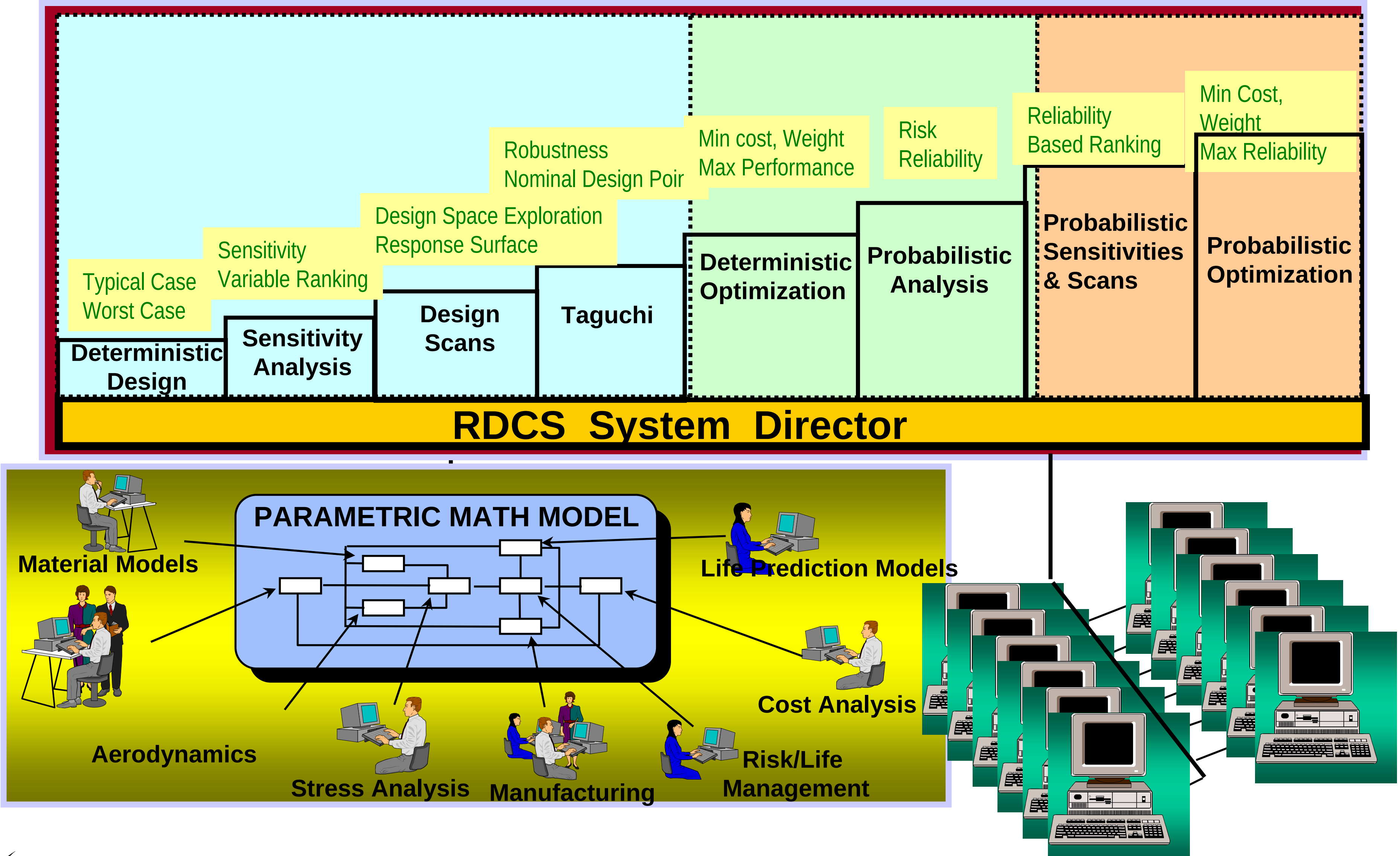
Validated By

Demonstrations
Focused on Recreating Existing Data, Precluding Persistent Problems, and Independent Peer Assessment

AIM-C Software Architecture

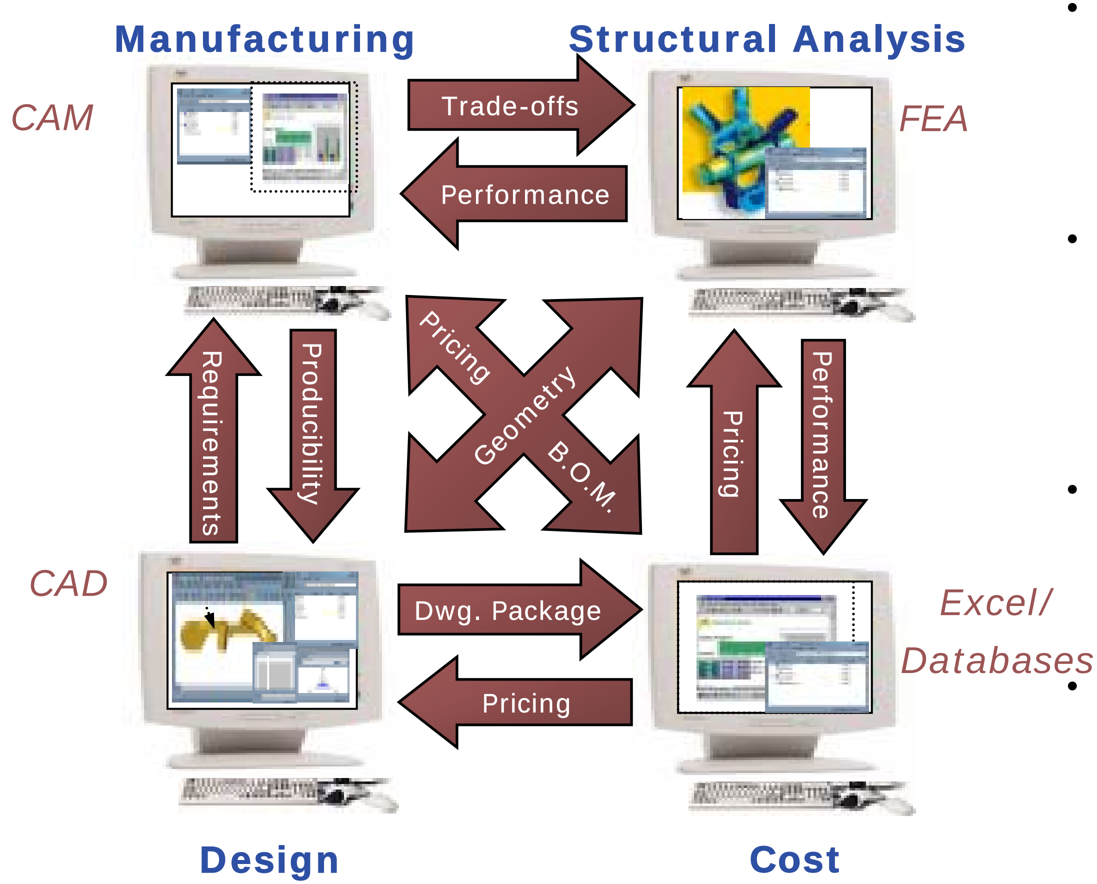


Robust Design Computational System



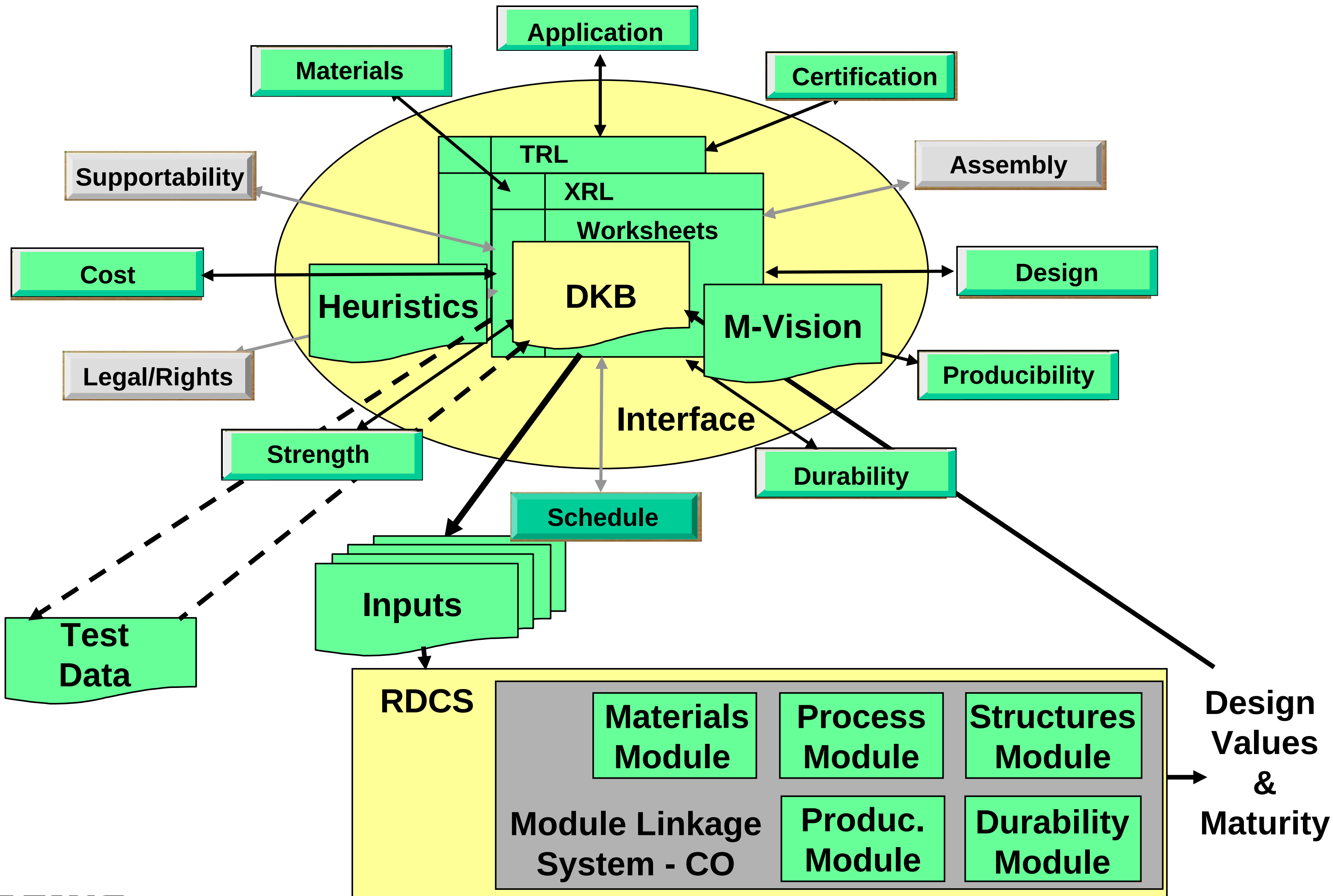
The Oculus Integration System

CO™: *A Plug & Play Modeling Environment*

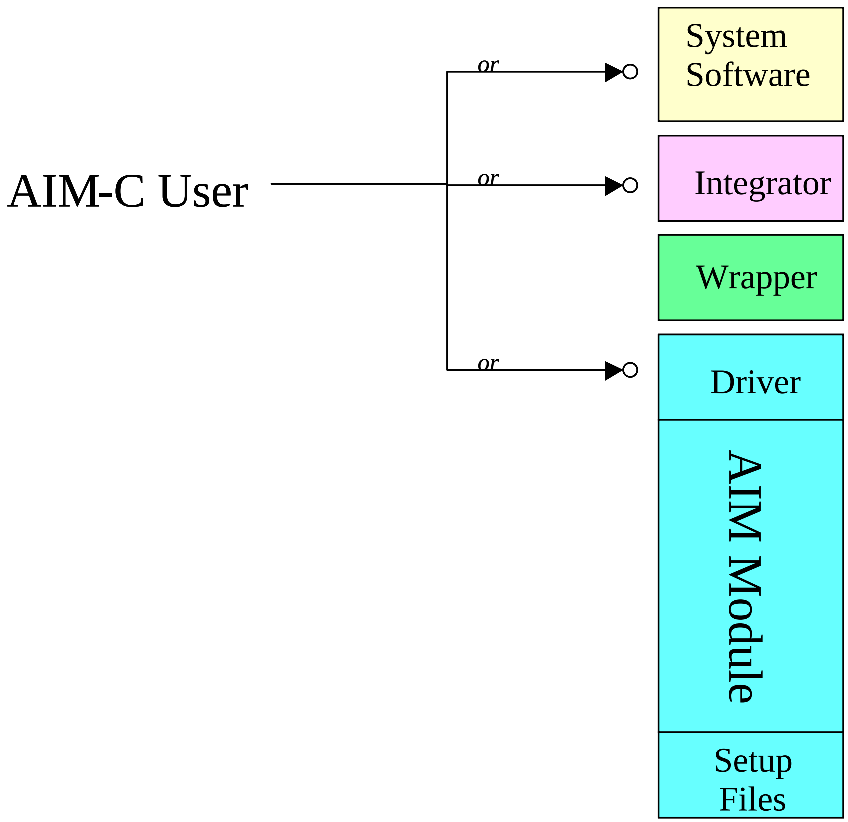


- **Integrates Data and Software Applications on-the-fly**
  - Drag & Drop, Plug & Play
  - Simple to create, modify, manage, maintain
- **Enables Real-time data sharing between applications**
  - Secure
  - Controlled
  - Intra/Internet
- **Platform Independent**
  - Distributed
  - Neutral to Platforms and Applications
- **Increases Value of Previous Investments**
  - Software
  - Hardware
  - Networks

AIM-C System Vision



The User Is Able to Run the Module At *Three* Different Levels



1. Through the System Software
2. Through the Integration Software
3. *For trouble-shooting, and validation, the individual modules can be ran directly from a driver program.*

How Will the System Be Used?

Web-Driven

- Accessed via Internet
- Used via Internet
- Application file local
- DOME enabled
- Modules available anywhere
- Configuration controlled by user
- Application file contains configuration info

Most flexible

Web-Based

- Downloaded from Internet
- Used locally to create application file
- Application file local
- Modules & S/W available few locations
- Configuration controlled by application file
- DOME enables remote access to modules

Most controlled

Stand Alone

- Accessed locally
- Used locally to create application file
- Application file local
- Modules & S/W available locally
- Configuration controlled by application file

May be only way for classified programs to use AIM-C

Methodology Ground Rules

a. Integrate the building block approach to insertion.
b. Involve each discipline in maturation.
c. Focus tests on needs identified by considering existing knowledge and analyses.
d. Target long lead concerns, unknowns, and areas predicted to be sensitive to changes in materials, processing, or environmental parameters

AIM Uses Knowledge, Analysis, and Test to Accelerate Insertion

Conventional Building Block Approach to Certification

Application Requirements	Target Properties	Supplier Offerings	Trade Studies	Fabrication Studies	Allowables Development	Full Scale Fab & Test
3 Months	3 Months	3-6 Months	2-6 Months	2-6 Months	6-18 Months	12-24 Months

Critical Details Fab & Test	Subcomponent Fab & Test	Component Fab & Test
2-6 Months	2-6 Months	2-6 Months

Time Reduction

Cost Reduction

Risk Reduction

The AIM Focused Approach to Certification

Application Requirements	Trade Studies	Design Features	Allowables Development	Full Scale Fab & Test
3 Months	3 Months	2-6 Months	4-9 Months	12-24 Months
	Supplier Offerings	Manufact. Features	Risk Reduction Fab & Test	
	3-6 Months	3-6 Months	4-9 Months	
	Target Properties	Key Features Fab & Test		
	2-6 Months	2-6 Months		

35% Reduction in Total Time to Certification

45% Reduction in Time to Risk Reduction

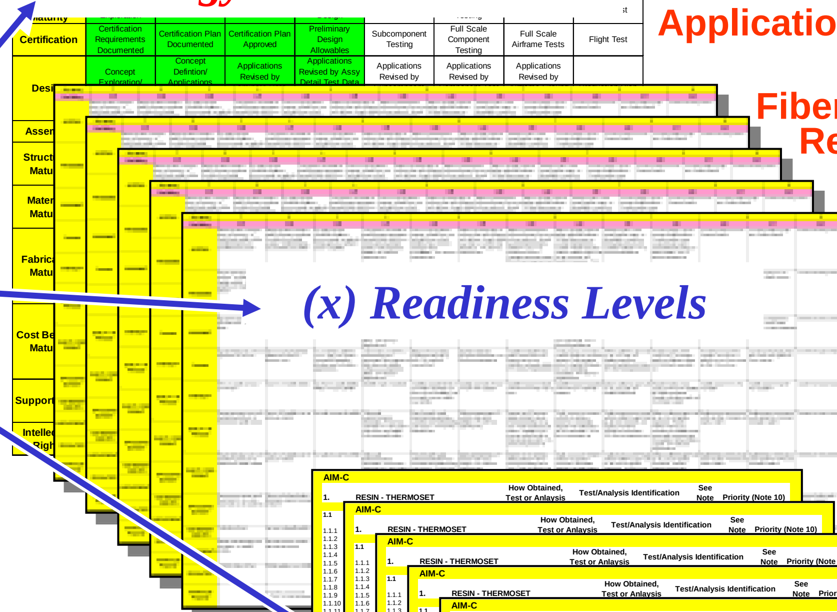
Methodology – Tool Sets

Tool Sets:

- *Technology Readiness Level* (TRL) Definitions/Chart/Worksheet
- *(x) Readiness Level* (xRL) Definitions/Charts/Worksheets
- *Technical Requirements* Definitions
- Physics/Science Based Models
- Math/Statistics Models & Functions
- Heuristic Models
- Relational Data Bases for Information Storage/Retrieval
- Usage Scenarios
- Other

Technology Readiness Levels

For Aerospace Applications



(x) Readiness Levels

Fiber
Resin
Prepreg
Fabrication
Assembly
Quality
Other

AIM-C
RESIN - THERMOSET
How Obtained, Test or Analysis
Test/Analysis Identification
See Note
Priority (Note 10)

- *Detailed Technical Properties/Characteristics*
- *Primary Test/Analysis Methods*
- *Secondary Test/Analysis Methods*
- *Sequencing Requirements*
- *Data Requirements*
- *Quality Requirements*

Fiber
Resin
Prepreg
Processing
Producibility
Lamina
Laminate
Durability
Elements

Technology Readiness Levels

TRL	1	2	3	4	5	6	7	8
Application Risk	Very High	High	High - Med	Med - High	Medium	Med - Low	Low	Low - Very Low
Application Maturity	Concept Exploration	Concept Defintion	Proof of Concept	Preliminary Design	Design Maturation	Component Testing	Ground Test	Flight Test
Certification	Certification Requirements Documented	Certification Plan Documented	Certification Plan Approved	Preliminary Design Allowables	Subcomponent Testing	Full Scale Component Testing	Full Scale Airframe Tests	Flight Test
Design	Concept Exploration/ Potenital Benefits Predicted	Concept Defintion/ Applications Revised by Lamina Data (Coupons)	Applications Revised by Laminate Data (Coupons)/ Design Closure	Applications Revised by Assy Detail Test Data (Elements)/ Preliminary Design	Applications Revised by Subcomponent Test Data/ Design Maturation	Applications Revised by Component Test Data/ Ground Test Plan	Applications Revised by Airframe Ground Tests/ Flight Test Plan	Production Plan
Assembly	Assembly Concept	Assembly Plan Defintion	Key Assembly Detail Defintions	Key Assembly Details Tested	Subcomponents Assembled	Components Assembled	Airframe Assembled	Flight Vehicles Assembled
Structures Maturity	Preliminary Properties-Characteristics	Initial Properties Verified by Test	Design Properties Developed	Preliminary Design Allowables	B-Basis Design Allowables	A-Basis Design Allowables		
Materials Maturity	Lab-Prototype Materials	Pilot Production Materials	Pre-Production Materials	Production Materials/ Material Specs			EMD Material Supplied	LRIP Material Supplied
Fabrication Maturity	Unfeatured-Panel Fabrication	Feature Based Generic Small/Subscale Parts Fabricated	Property-Fab Relationships Tested/ Target Application Pilot Production of Generic Full Size Parts	Process Specs/ Effects of Fab Variations Tested/ Elements Fab'd/ Production Representative Parts Fab'd	Subcompnents Fab'd	Full Scale Components Fabricated	EMD Fabrication	Low Rate Initial Production (LRIP)
Cost Benefits Maturity	Cost Benefit Elements ID'd & Projected	ROM Cost Benefit Analysis	Cost Benefit Analysis Reflect Size Lessons Learned	Cost Benefit Analysis Reflect Element and Production Representative Part Lessons Learned	Cost Benefit Anlysis Reflect Subcomponent Fab & Assembly Lessons Learned	Cost Benefit Anlysis Reflect Component Fab & Assembly Lessons Learned	Cost Benefit Anlysis Reflect EMD Lessons Learned	Cost Benefit Anlysis Reflect LRIP Lessons Learned
Supportability	Repair Items/Areas Identified	Repair Materials & Processes Identified	Repair Materials & Processes Documented	Fab Repairs Identified	Fab Repair Trials/ Subcomponent Repairs	Component Repairs	Production Repairs Identified	Flight Qualified Reapirs Documented
Intellectual Rights	Concept Documentation	Patent Disclosure Filed	Proprietary Rights Agreements	Data Sharing Rights	Vendor Agreements	Material and Fabrication Contracts	Production Rate Contracts	Vendor Requal Agreements

Methodology – What & When

Technology Readiness Level

- 10. Disposal
- 9. Production
- 8. Flight Test
- 7. Ground Test
- 6. Component Test
- 5. Design Maturation (Subcomponents)
- 4. Preliminary Design (Stable Mat'l & Process + Elements)
- 3. Proof of Concept Prototype
- 2. Concept Definition
- 1. Concept Exploration

System

Activity Steps Moving to Certification

(x) Readiness Level

- 9. Industry Std
- 8. Production
- 7. Qualified Mat'l/Process
- 6. Pre-Production
- 5. Pilot Production
- 4. Lab/Prototype Production
- 3. Beaker/Bench Product
- 2. Theoretical/Beaker Product
- 1. Concept Exploration

Activity Steps Moving to Qualification

Technologist Activity Description

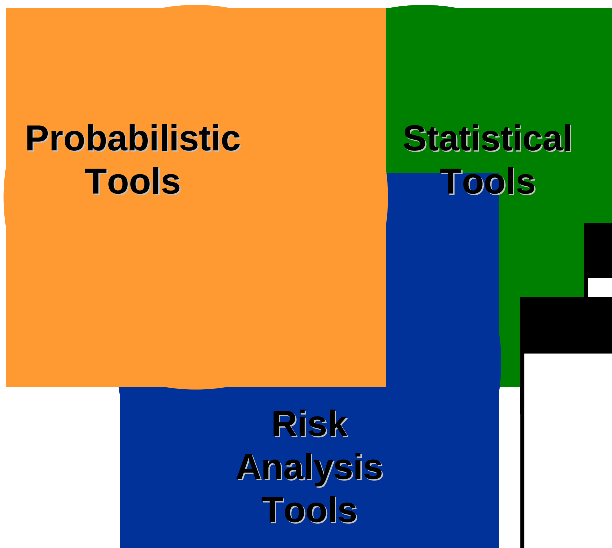
Final Capabilities

Expanded Capabilities

Preliminary Capabilities

Preliminary Investigations, Research, Development

Understanding Uncertainty – The Benefit of Linked Simulation Tools and Methodology



Coupon Failure Modeling Errors and Uncertainties

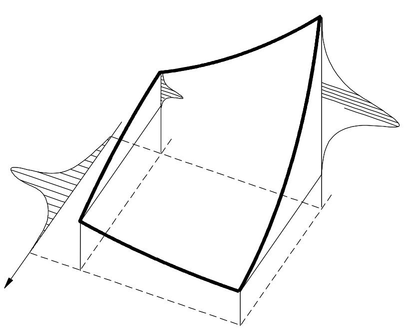
Producibility Uncertainty

Prepreg Module Uncertainty Considerations

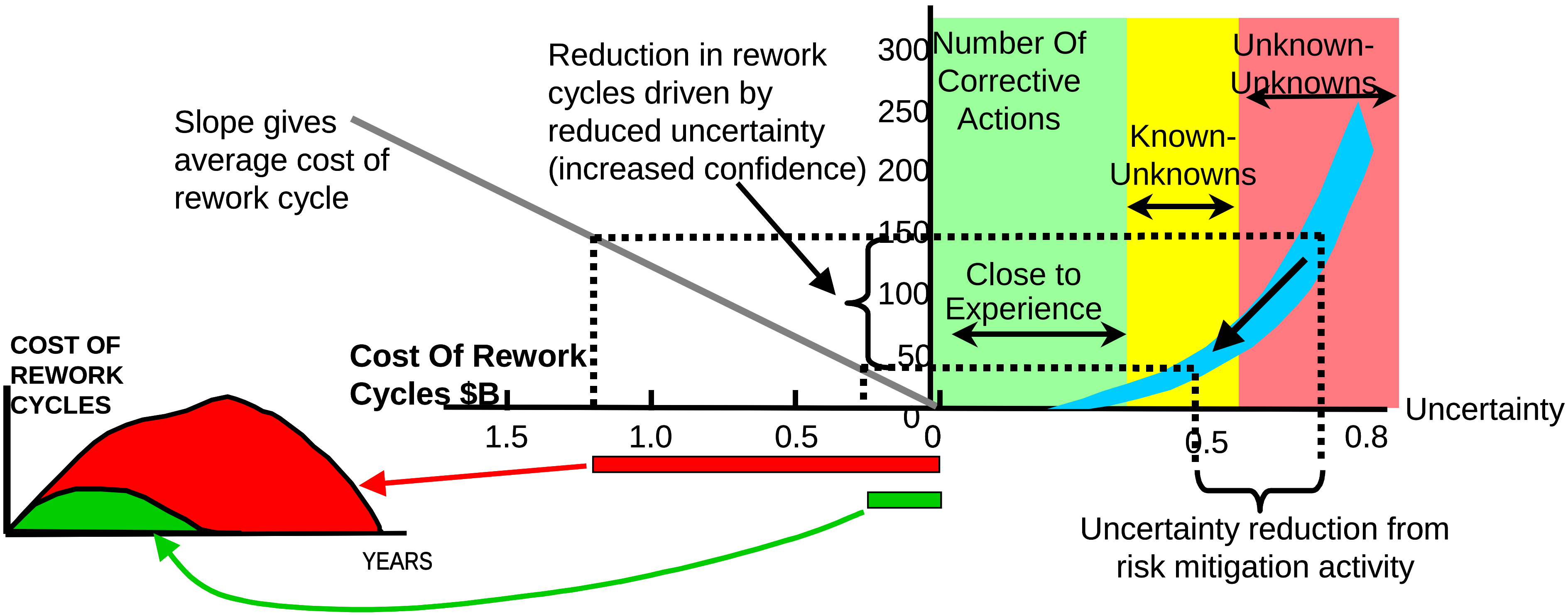
Resin Module Uncertainty Considerations

Modeling of the Process

	Inherent variations associated with physical system or the environment (Aleatory uncertainty) Also known as variability, stochastic uncertainty E.G. manufacturing variations, loading environments	Uncertainty due to lack of knowledge (Epistemic uncertainty) inadequate physics models information from expert opinions.	Known Errors (acknowledged) e.g. round-off errors from machine arithmetic, mesh size errors, convergence errors, error propagation algorithm	Mistakes (unacknowledged errors) human errors e.g error in input/output, blunder in manufacturing
Temperature Boundary Conditions	Variation in temperature throughout an autoclave; variation in bagging thickness across part	Modeling of heat transfer coefficient of autoclave includes pressure effect but not shielding of part. Assumptions made about tool-part resistance.	Convergence of mesh must be checked. Time-steps and temperature steps must be small enough.	Errors in setup files, and other initialization procedures. Errors/bugs in code.
Tool Part Interaction	Part to part and point to point variations in tool finish and application of release agent	Tool-part interaction is very complex, and very local effects may at times be significant	Current model of tool-part interaction is too simple for large parts on high CTE tools.	Errors in calibrating the tool-part interaction
Layup	Variation in lay-up during hand or machine lay-up.	The layers are smeared within an element and it is assumed that the smeared response is representative		Error in defining layup, or alternatively errors in the manufactured part compared to model
Residual Stresses	Many parameters can affect residual stress: local fiber volume fraction, …	Micro-stresses are considered to be independent of meso-stresses; there are few independent measurements of residual stress.	The formulation is believed to be most accurate when the cure cycle temperature is higher than the Tg. Otherwise the residual stress calculated can be an overestimate.	Errors in material property definition, errors in coding, errors in integrating process and structural models.

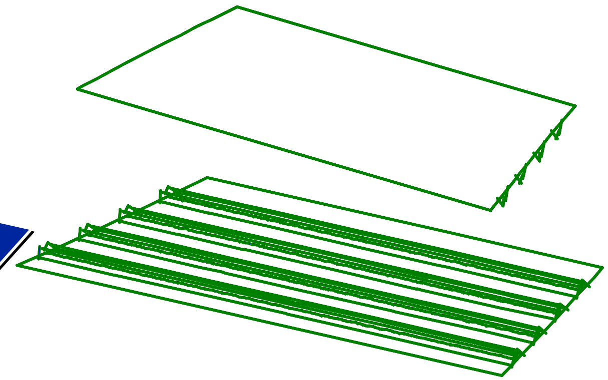


AIM-C Reduces Time and Cost of Insertion through Orchestration of Knowledge, Analysis, and Test

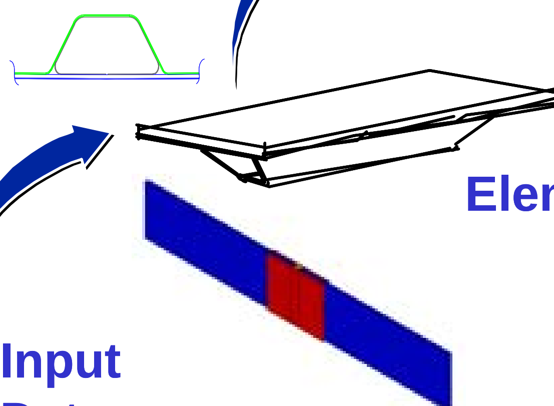


Hat Stiffener Run-out Analysis Validation Tests

Variables and interactions exercised include processing effects and defects.

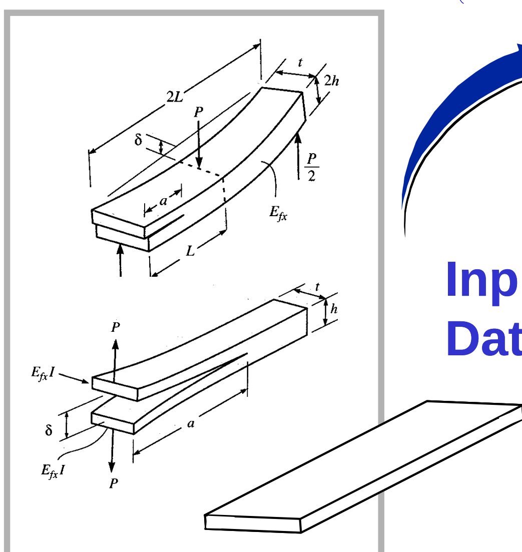


Analysis Validation Tests



Elements

- Static Strength
- Durability
- Damage Tolerance



Input Data

- DCB and ENF
- J_1 and ε_{eqv} Laminates/Joints

The AIM-C System Provides a Methodology for Insertion Via Knowledge, Analysis, and Test

The Next Four AIM-C Presentations Will:

- Demonstrate an Analytical Approach to Establish the Processing Window
  - *"Exploration of Composites Processing Window and Producibility by Analysis" – Pete George*
- Describe a Software Tool That Links Process Induced Residual Stress to Structural Performance
  - *"Integration of Process Modeling and Stress Analysis Methods for Composite Materials" – Anthony Caiazzo*
- Show How Durability Will be Assessed Using Analysis/Test
  - *Methodology for Composite Durability Assessment – A. Kuraishi*
- Give Examples of Using Analytical Tools in Composite Design
  - *Robust Design of Composite Structure – Eric Cregger*

Back up

AIM Methodology: Criteria for Success

1. **Architecture**

- Open/controlled (secure/open)
- Platform independent (Intranet vs. Internet)

2. **Capabilities – at least 4 capabilities/modules**

   - Properties – time dependent properties
   - Durability/Lifing
   - Processing/Manufacturing/Producibility
   - Cost

AIM Methodology: Criteria for Success

3. Features/Outputs

- Demonstrate that the methodology reproduces the DKB
- Demonstrate that "a rogue" process spec will result in a flag by the system
- Demonstrate that a rogue "geometry" results in an "un-producible" flag
- Demonstrate the ability of the system to direct experiment – to direct an experiment to determine a "benchmarking" parameter, or a basic physical quantity. (validation/calibration)

Means to Impart Methodology

a. User interface screens/prompts
b. Linked text files
c. Software documentation
d. Training
e. Methodology/process definition and change procedures document

Material Insertion Methodology

Methodology Covers:

- *What* Needs to be Done?
- *When* is it Done?
- *How* is it Done?
- *Why* is it Done?

Methodology Has to Accommodate:

- Designer Perspective + Others
- Product Certification Requirements
- Material Qualification Requirements
- Multiple Tool Sets
- Testing
- Traceability
- Integration

What, When, Why

How

Tool Sets:

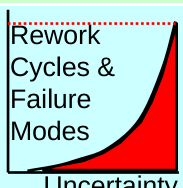
- *Technology Readiness Level* (TRL) Definitions/Chart/Worksheet
- *(x) Readiness Level* (xRL) Definitions/Chart/Worksheet
- *Technical Requirements* Definitions
- Definitions/Worksheets/Templates
- Physics/Science Based Models
- Math/Statistics Models & Functions
- Heuristic Models
- Relational Data Bases for Information Storage/Retrieval
- Usage Scenarios
- Other

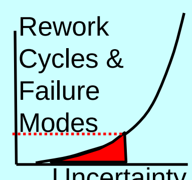
AIM-C Methodology Impact on Traditional Qualification

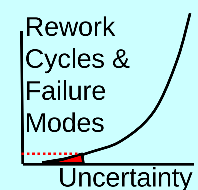
Structures Maturity		Non Structural Applications		Secondary Structural Applications		Primary Structural Applications	
AIM-C Application	AIM-C CAT Run to Identify Critical Factors for Analysis, Test, Demonstration To Fill Screening Database Requirements	Screening Database Exists Broad Range of Data Limited Replications	AIM-C CAT Run to Define Preliminary Design Database Requirements	Preliminary Design Database Exists Full Distribution on Few Key Properties	AIM-C CAT Run to Define Design Database Requirements For a Desired Confidence Level	Allowables Database Exists Full Distribution on Key Properties	AIM-C Run to Define Remaining Design Database Requirements	Production Readiness Established and System Validated with Confidence Metrics

TRL	1	2	3	4	5	6	7	8+
Confidence Lvl	10%	20%	30%	40%	50%	60%	70%	80%+

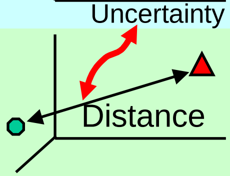
Criteria-Based Assessment





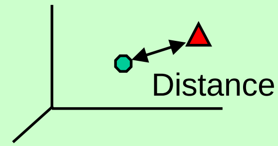


Quantitative Assessment via Distance From Experience

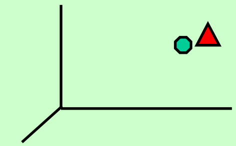


Design Point
Experience Data Point

Axes are the "drivers" for this application



Distance from experience ("similar" hardware, building block tests, and/or anchor points for models) measured using "anchored" models



Re-creation of DKB and AIM Dem/Val

IDR
Sep/Oct 92

Hat Stiffened Panel
(AS4/977-3 Uni and Cloth)
DKB 08/03; Validation 02/04

CDR
Jun 94

IM7/977-3
DKB 06/02

Apr 91

AS4/977-3
DKB 10/02

Oct 91

Dec 91
Decision to use AS4/977-3

(1) Re-create a DKB for IM7/977-3

(2) Re-create a DKB for AS4/977-3

(3) Provide a DKB for Hat Stiffened Panel (HSP)
Demonstration and Validation of the AIM-C System

Phase 1 Schedule

April 04 – Final Documentation and Software Deliverable
•Feb 04 – Final Briefing – All Teams – Phase 1 Technical Effort Concludes – Full System Validation and Compelling Demonstration Validated
Jan 04 – AIM-C CAT Training
•Nov 03 – Blind Validation Complete
•Aug 03 – Demonstration/Validation – AIM-C CAT applied to hat stiffener insertion technology
Jun 03 – DARPA's presentation for Phase 2
•May 03 – AIM-C CAT Demonstration to DARPA; Separate Quarterly Review
•Feb 03 – Full AIM Team Quarterly Review; Validation of AIM-C CAT Alpha-Modules and System; Alpha Version of Modules
•Nov 02 – Methodology linked to CAT Tools
•Aug 02 – Alpha- Version of Interface Software
•May 02 – Five CAT demonstrations; certification team participates